ERL-0216-TR

AR-002-631

AD A112001

DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

ELECTRONICS RESEARCH LABORATORY

DEFENCE RESEARCH CENTRE SALISBURY
SOUTH AUSTRALIA

TECHNICAL REPORT

ERL-0216-TR

THE CHOICE OF A LASER FOR AIRBORNE DEPTH SOUNDING

J. RICHARDS and D. REES

Approved for Public Release

COPY No.

SEPTEMBER 1981

AR-002-631

DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

ELECTRONICS RESEARCH LABORATORY

TECHNICAL REPORT

ERL-0216-TR

THE CHOICE OF A LASER FOR AIRBORNE DEPTH SOUNDING

J. Richards and D. Rees

S U M M A R Y

(U) A conventional electro-optically Q-switched laser resonator and a polarisation coupled crossed-Porro resonator are compared for use in a frequency doubled neodymium doped yttrium aluminium garnet (Nd:YAG) laser. Laser rod diameters of 3, 4 and 5 mm are evaluated in each resonator to determine the relative merits of each rod/resonator combination in producing the required 532 nm frequency doubled output. The effect of repetition rate over the range 15 Hz to 250 Hz on the performance of each resonator and rod is examined. A lifetest is used to determine the likely problem areas in both resonators. Recommendations are made concerning the size of rod and type of resonator configuration best able to meet the requirements of a laser suitable for airborne depth sounding.

POSTAL ADDRESS: Chief Superintendent, Electronics Research Laboratory,
Box 2151, GPO, Adelaide, South Australia, 5001.

TABLE OF CONTENTS

LIST OF FIGURES

1. INTRODUCTION

The laser airborne depth sounder (LADS) is being developed at the Defence Research Centre Salisbury for use by the Royal Australian Navy in charting coastal waters(ref.1, 2 and 3). The LADS system requires visible and infrared laser radiation such tbat, at an aircraft height of 500 m, the visible laser radiation falls on a 10 m by 10 m grid over a swathe width of 270 metres. The visible laser radiation is used to sense the depth of the sea bottom below the surface. The infrared laser radiation, which is projected immediately below the aircraft, is used to determine the height of the aircraft above the sea.

A Q-switched, frequency doubled, neodymium doped yttrium aluminium garnet (Nd:YAG) laser is suited to this task since the fundamental infrared (IR) laser radiation at 1064 nm does not penetrate the sea and hence allows accurate detection of the surface. The frequency doubled laser output at 532 nm is near the peak transmission of coastal waters which enbances the probability of getting a signal back to the aircraft from the sea bottom.

In some of the early work associated witb finding a laser that was suitable for LADS, a pulse transmission mode (PTM) Nd:YAG laser was studied and initially favoured for this application because of its abilty to generate short pulses(ref.4). Experience with a conventional PTM laser sbowed that when thermally induced birefringence was present in the laser rod the efficiency decreases and the techniques necessary to compensate for this were considered too complex. Nortbam et al(ref.5) have developed a complicated PTM laser which is able to operate in the presence of high thermal stresses, but they have only achieved peak power outputs of 400 kW, which is considerably below that required for the LADS application.

The specification for the LADS laser(see Table I), requires that a short pulse (5 ns) of visible (532 nm) laser radiation be generated with a peak power of 1 MW at a repetition rate of 168 Hz. Table 1 also shows that the required life of the laser before any major overhaul is 1000 hours. These requirements impose a number of constraints on any resonator configuration. The resonator length is made as short as possible to assist in obtaining a short pulse duration. Efficiency and reliability are important since the recommended wall loading of the flashlamp must not be exceeded and any system components must not be damaged otherwise the required life will not be achieved.

The work described in this report is concerned with the suitability of two types of laser resonator to fulfil this task. These resonators are the electro-optically Q-switched conventional type and the electro-optically Q switched polarisation coupled crossed Porro (PCCP). The influence of rod diameter on the suitability of these resonators to meet the LADS specification is considered.

2. RESONATOR DESCRIPTION

Both resonators use a common pump cavity, polariser, Pockels cell and have the same resonator length. The Porro prisms of the PCCP are replaced by mirrors in the conventional resonator. The IR output exits from the polariser in the PCCP and from the transmitting mirror in the conventional resonator.

2.1 Polarisation coupled crossed Porro resonator

The operation of this resonator is described in references 6 and 7. It contains two Porro prisms, one at each end of the resonator, with their roof-edges inclined at approximately 90° to eacb otber. The prism nearest the Pockels cell is adjusted to have its roof-edge at 45° to the plane of polarisation of the energy passed by the polariser since tbis gives greatest hold-off. The hold-off achieved with zero bias applied to the Pockels cell is sufficient to prevent breakthrough, (the occurrance of un-Q-switched output), at the power levels used in this study. The prism at the other end of the resonator is rotated to optimise the amplitude and shape of the output pulse which exits through the side of the polariser. A schematic diagram of the resonator is shown in figure 1.

2.2 Conventional resonator

This resonator is shown in figure 2; it includes a 100% reflecting mirror at the Pockels cell end and a partially reflecting output mirror at the other end of the resonator. The maximum output under Q-switched conditions is set by the onset of breakthrough caused by the less-than-ideal Pockels cell. Breakthrough is observed to both reduce the output and cause large pulse-to-pulse variations. Further it is recognised(ref. 8) that local hot-spots (high intensity regions in the beam), occur wben breakthrough is present. The breakthrough threshold may be raised by using a quarter-wave plate to provide hold-off and the Pockels cell to cancel the phase shift introduced by the quarter-wave plate at the moment Q-switching is desired.

There is one fundamental difference between the two types of resonator. When the PCCP resonator is tuned for maximum output the effective coupling from the resonator is about 50%, but it cannot be increased above this level since only one polarisation is coupled out. Consequently the energy within the PCCP resonator cannot be minimised to reduce the probability of optical damage. With the conventional resonator the coupling can be varied by changing the reflectivity of the output mirror, this permits the choice of reflectivity to reduce the energy within the resonator thus minimising the probability of optical damage to components within the resonator.

The output mirror used in the conventional resonator for 3 and 4 mm diameter rods has a reflectivity of 10%. It is necessary with the 5 mm rod to use an output mirror reflectivity of 20% in order to obtain the required output within the rating of the flashlamp.

2.3 Frequency doubler

The efficiency of the frequency doubler in converting the 1064 nm radiation from the resonator to 532 nm energy determines the 1064 nm radiation required from the resonator and in turn the average power in the flashlamp. Experience has shown a frequency doubler using angle-tuned deuterated cesium dihydrogen arsenate (CD*A) cut for 50°C operation, to be tbe most suitable in this application. The same frequency doubler, not shown in figures 1 and 2 is used with both resonators.

2.4 Flashlamp

Two problems occur when operating flashlamps at high repetition rates and high average powers. These are:

> The amplitude and timing jitter that occurs in the peak current and hence light output.
>
> The achievable lifetime of the flashlamp.

It was found(ref.9) that amplitude and timing jitter can be minimized if a continuous discharge current (simmer) of 4 A is passed througb the flashlamp during operation. A reasonable lifetime can be obtained by ensuring that the maximum average power dissipation on the walls of the flashlamp is below 200 W/cm^2. Thus for adequate lifetimes on a 75 mm arc length, 5 mm bore flashlamp operating at 168 Hz the pulse energy should not exceed 12 J. Recent experience with a 50 mm arc length 4 mm bore flashlamp operating at about 200 W/cm^2 have confirmed these expectations since lifetimes at 168 Hz in excess of 400 hours have been obtained(ref.10).

2.5 Discussion of results

The relative ability of the conventional and the PCCP resonator to produce the required output of 5 mJ of 532 nm laser radiation with a pulse width of 5 ns, that is 1 MW peak output, is dependent on the rod diameter. Rod diameters of 3, 4 and 5 mm were available for this study.

Each rod in either resonator is capable of generating the required 532 nm output of 5 mJ as is shown in figure 3. The PCCP resonator, because of its more optimum coupling, provides the required output at a lower input energy. However, as shown in figure 4, the conventional resonator gives a shorter pulse than the PCCP resonator for the same output energy. This is mainly because more input energy is required in the conventional resonator and the resultant bigher gain leads to a shorter pulse.

When the effect of repetition rate on 1064 nm output from both resonators is examined, the output from the PCCP resonator is found to be independent of repetition rate, provided the output coupling Porro is rotated to optimise the output from the resonator at each repetition rate. The 1064 nm output from the conventional resonator as a function of repetition rate is shown in figure 5. The input energy to the flasblamp is set to the level which would give 5 mJ of 532 nm output at 168 Hz. All outputs decrease with increasing repetition rate. The output at 168 Hz for all rod diameters is about 70%. The decrease in output is dependent on the mirror output coupling as is shown in figure 5.

Examination of the resonator components after the series of tests and a lifetest at the operational level showed that there was no damage to the optical surfaces at the end of the conventional resonator lifetests, whereas all rods were damaged in the PCCP resonator lifetests. The lifetest on a 5 mm diameter rod in the PCCP resonator showed no decrease in output after 100 hours at 168 Hz, but the ends of the rod were found to be damaged. The 3 mm diameter rod was damaged during the first hour of operation and there was a decrease in output due to this damage. Figure 6 shows some of the damage experienced with a 4 mm diameter rod, the damage extended to a depth of 0.25 mm after 1 hour of operation at 168 Hz.

The damage in the PCCP resonator is thought to occur because some regions of the beam within the resonator are not coupled out. This lack of coupling is caused by varying polarisation states across the resonator beam due to the induced birefringence in the rod at high repetition rates. In this case localised high energy densities can occur inside the resonator and can cause damage to optical surfaces. Any damage so produced may not be immediately catastrophic to the resonator's performance because it occurs in regions of the rod which have minimal effect on output. However, damaged areas are likely to grow due to their increased absorption and could eventually extend into regions of the rod producing useful output, with a consequent detrimental effect.

3. CONCLUSIONS AND RECOMMENDATIONS

The report shows that the 3, 4 and 5 mm diameter Nd:YAG rods are all capable of generating the required 5 mJ of 532 nm output in both conventional and polarisation coupled crossed-Porro (PCCP) resonators. The pulse-width requirement of 5 ns excludes the 5 mm rod in the PCCP resonator since 5.8 ns was the shortest pulse obtainable in this instance. The 3 mm rod does offer the advantage of generating the required output and pulse width more effectively in both resonators.

The effect of increasing repetition rate does not favour any one rod diameter in the conventional resonator and the effect of repetition rate can be eliminated in the PCCP resonator. A claimed advantage of the PCCP resonator over the conventional resonator is the insensitivity of the former to misalignment. Experience with conventional resonators has not revealed any misalignment problems either in the laboratory or in airborne applications, hence in the LADS context there is no practical difference between the two resonators in maintaining alignment.

The critical factor is the likely lifetime of the components. Since the PCCP resonator, in its present form, damages optical components within the resonator, the final choice must be the conventional resonator with 3 mm diameter rod. It is possible that some depolarizing elements currently being developed may eliminate the localised high power densities causing damage(ref.11). However, even if they operate perfectly, the PCCP resonator would still be more likely to damage components than the conventional resonator because the latter has much lower resonator power levels.

The following is recommended for the LADS laser system:

(a) The laser should use a conventional resonator configuration

(b) The output coupling from the conventional resonator should be approximately 90%. This will minimize the power within the resonator and thus reduce the probability of optical damage. At the same time it will help reduce the pulse widtb by reducing the decay time constant of the resonator. The resonator length should also be as short as possible to help minimize pulse width.

(c) The 3 mm diameter Nd:YAG rod is the most suitable in the LADS application. In order to reduce the average power loading of the flashlamp the arc length of the flashlamp and also the active length of the Nd:YAG rod should be a minimum of 70 mm.

(d) The flashlamp should be used with a simmer current of 4 A to minimize amplitude and timing jitter and prevent extinction wben operating at high repetition rates.

(e) A Pockels cell and quarter-wave plate combination sbould be used in the Q-switching operating to help prevent breakthrough and minimize pulse to pulse variations.

(f) All elements within the resonator should have minimum loss thus reducing the energy required to obtain the necessary output and bence prolonging the life of the flashlamp.

(g) The frequency doubler used sbould be angle-tuned deuterated cesium dihydrogen arsenate (CD*A) cut for 50°C operation. Angled-tuned CD*A has a higher long term damage threshold than 90° phase-matched CD*A, and is more efficient than other frequency doublers at the power densities and beam divergences used.

4. ACKNOWLEDGEMENTS

The assistance of P. Wilsen, C. Jones and G. Roberts in obtaining the results for this report is acknowledged.

REFERENCES

No.	Author	Title
1	Clegg, J.E. and Penny, M.F.	"Depth Sounding from the Air by Laser Beam" Journal of Navigation, Vol.31, p52, 1978
2	Calder, M.	"WRELADS - The Australian laser depth sounding system" International Hydrographic Review, LVII(1), p31, January 1980
3	Abbot, R.H. Watts, G.J. and Penny, M.F.	"WRELADS1 Trials Report" ERL-0026-TR, 1978
4	See, B.A.	"The Pulse Transmission Mode Laser" ERL-0167-TM, September 1980
5	Northam, D.B. Guerra, M.A. Mack, M.E. Itzkan, I. and Deradourian, C.	"High repetition rate frequency doubled Nd:YAG laser for airborne bathymetry" Applied Optics, Vol.20, No.6, p968, March 1980
6	Chun, M.K. and Teppo, E.A.	"Laser Resonator: An Electrooptically Q-Switched Porro Prism Device" Applied Optics, 15, 8, p1942, August 1976
7	See, B.A. Seymour, R.S. and Fueloep, K.J.	"An Assessment of the Crossed Porro Prism Resonator" ERL-162-TM, August 1980
8	Koechner, W.	"Solid State Laser Engineering" Springer-Verlag, N.Y., p 421, 1976
9	Richards, J. Rees, D. Fueloep, K.J. and See, B.A.	"The Operation of Krypton Filled Flashlamps at High Repetition Rates" In preparation.
10	Rees, D. and Wilsen, P.J.	"Evaluation of the Performance of a Laser for Airborne Depth Sounding" ERL-0190-TR, 1981
11	See, B.A.	Australian Patent Application PE 2077, 1981

TABLE 1. LASER SPECIFICATION

532 nm Energy output	5 mJ
1064 nm Energy output	2 mJ
532 nm Pulse width (FWHM)	5 ns
repetition rate	168 Hz
input energy to flashlamp	< 10 J
component lifetime (excluding flashlamp)	> 1000 hours

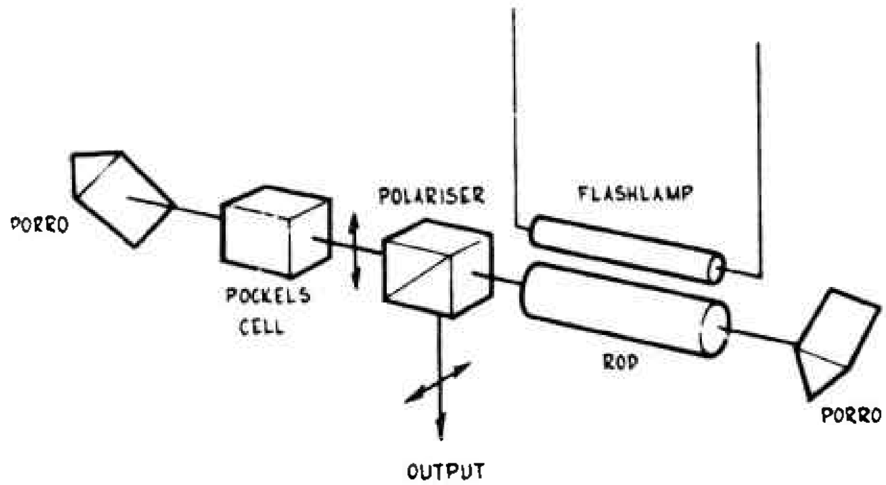

Figure 1. Schematic diagram of polarisation coupled crossed-Porro resonator

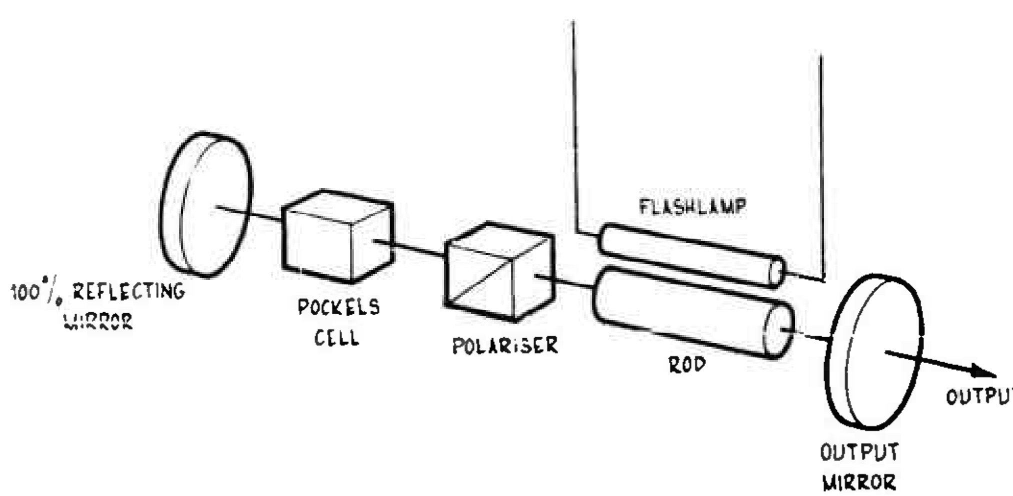

Figure 2. Schematic diagram of conventional Q-switched resonator

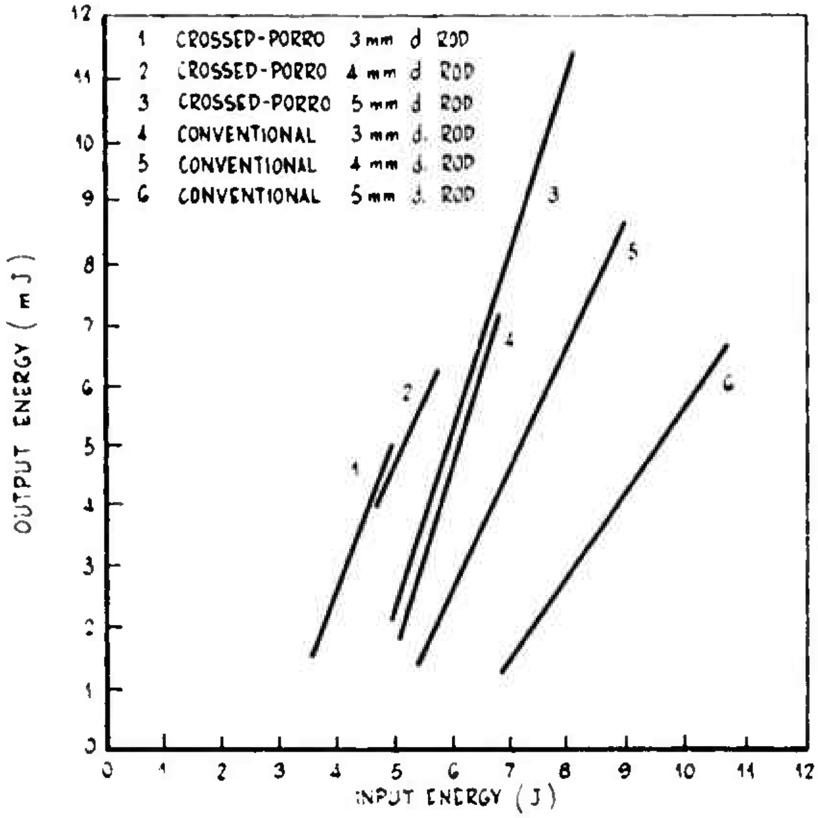

Figure 3. Efficiency in generating 532 nm output as a function of resonator type and rod diameter

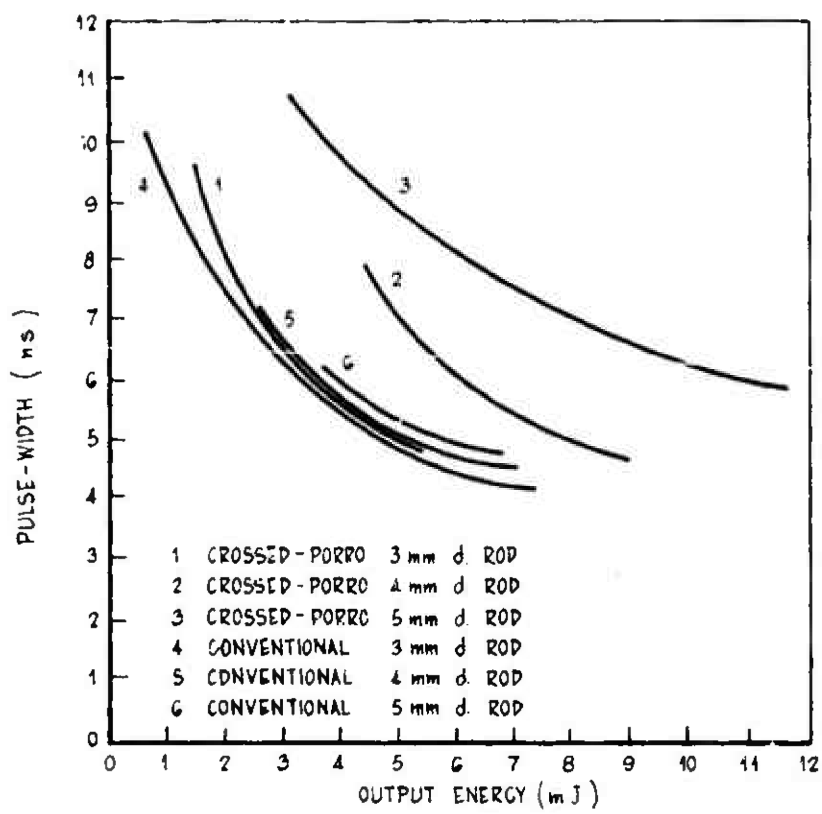

Figure 4. 532 nm pulse-width as a function of output energy, resonator type and rod diameter

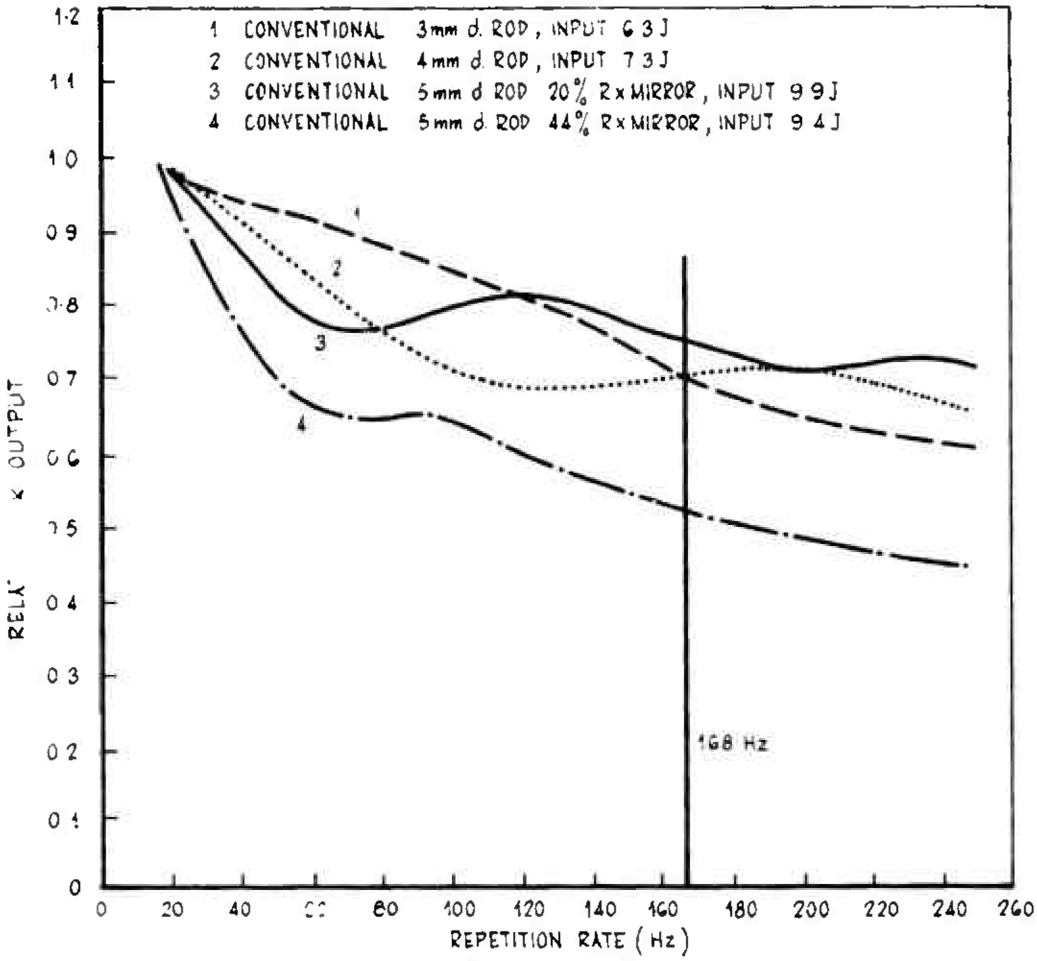

Figure 5. Relative I.R. output as a function of repetition rate and rod diameter

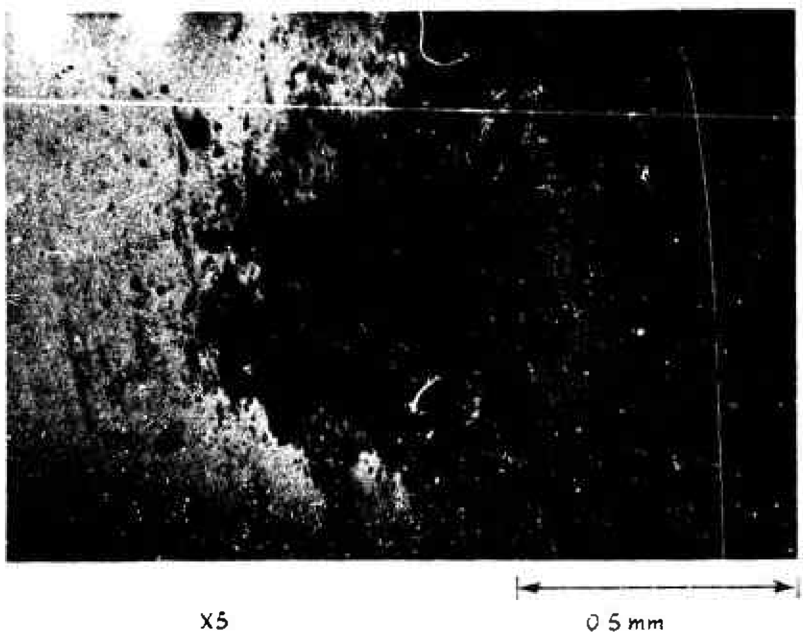

Figure 6. Damage to end of 4 mm laser rod used in crossed-Porro resonator

DISTRIBUTION

	Copy No.
EXTERNAL	
In United Kingdom	
Defence Science Representative, London	No copy
British Lending Library Division, Boston Spa Yorkshire	1
Technology Reports Centre, Orpington Kent BR5 3RF	2
Institution of Electrical Engineers, Hitchin Hertz SG5 IRJ	3
In United States of America	
Counsellor, Defence Science, Washington	No copy
National Technical Information Services, Springfield Va	4
Engineering Societies Library, New York NY 10017	5
Data Courier Inc., Louisville Ky 40202	6
In Australia	
Chief Defence Scientist	7
RAN Hydrographer	8 - 9
Deputy Chief Defence Scientist	10
Superintendent, Science & Technology Programmes	11
Controller, Projects and Analytical Studies	12
Navy Scientific Adviser	13
Director, Division of National Mapping, Department of National Resources	14
Director, Joint Intelligence Organisation (DDSTI)	15
Document Exchange Centre Defence Information Services Branch (for microfilming)	16
Document Exchange Centre Defence Information Services Branch for:	
United Kingdom, Ministry of Defence Defence Research Information Centre (DRIC)	17
United States, Defense Technical Information Center	18 - 29
Canada, Department of National Defence Defence Science Information Service	30
New Zealand, Ministry of Defence	31

Australian National Library	32
Director General, Army Development (NCO) Russell Offices for ABCA Standardisation Officers	
UK ABCA representative, Canberra	33
US ABCA representative, Canberra	34
Canada ABCA representative, Canberra	35
NZ ABCA representative, Canberra	36
Director, Industry Development, Regional Office, Adelaide	37
Defence Library, Campbell Park	38
Library, Aeronautical Research Laboratories	39
Library, Materials Research Laboratories	40
WITHIN DRCS	
Chief Superintendent, Electronics Research Laboratory	41
Chief Superintendent, Weapons Systems Research Laboratory	42
Chief Superintendent, Advanced Engineering Laboratory	43
Superintendent, Navigation and Surveillance Division	44 - 45
Senior Principal Research Scientist, Surveillance	46
Principal Officer, Night Vision Group	47
Principal Officer, Optical Techniques Group	48
Principal Officer, Electro-Optics Group	49
Principal Officer, Surveillance Systems Group	50
Authors	51 - 88
DRCS Library	89 - 90
Spares	91 - 95

DOCUMENT CONTROL DATA SHEET

Security classification of this page: UNCLASSIFIED

1 DOCUMENT NUMBERS	
AR Number:	AR-002-631
Series Number:	ERL-0216-TR
Other Numbers:	

2 SECURITY CLASSIFICATION	
a. Complete Document:	Unclassified
b. Title in Isolation:	Unclassified
c. Summary in Isolation:	Unclassified

3 TITLE

THE CHOICE OF A LASER FOR AIRBORNE DEPTH SOUNDING

4 PERSONAL AUTHOR(S):

J. Richards and D. Rees

5 DOCUMENT DATE:

September 1981

6 6.1 TOTAL NUMBER OF PAGES 10

6.2 NUMBER OF REFERENCES: 11

7 7.1 CORPORATE AUTHOR(S):

Electronics Research Laboratory

7.2 DOCUMENT SERIES AND NUMBER

Electronics Research Laboratory 0216-TR

8 REFERENCE NUMBERS

a. Task: NAVY 77/020

b. Sponsoring Agency:

9 COST CODE:

10 IMPRINT (Publishing organisation)

Defence Research Centre Salisbury

11 COMPUTER PROGRAM(S) (Title(s) and language(s))

12 RELEASE LIMITATIONS (of the document):

Approved for Public Release

Security classification of this page: UNCLASSIFIED

Security classification of this page: UNCLASSIFIED

13 ANNOUNCEMENT LIMITATIONS (of the information on these pages):

No Limitation

14 DESCRIPTORS:

a. EJC Thesaurus Terms

Lasers
Performance evaluation
Airborne operations
Depth finders
Infrared lasers

b. Non-Thesaurus Terms

LADS

15 COSATI CODES:

2005
1707

16 SUMMARY OR ABSTRACT:
(if this is security classified, the announcement of this report will be similarly classified)

A conventional electro-optically Q-switched laser resonator and a polarisation coupled crossed-Porro resonator are compared for use in a frequency doubled neodymium doped yttrium aluminium garnet (Nd:YAG) laser. Laser rod diameters of 3, 4 and 5 mm are evaluated in each resonator to determine the relative merits of each rod/resonator combination in producing the required 532 nm frequency doubled output. The effect of repetition rate over the range 15 Hz to 250 Hz on the performance of each resonator and rod is examined. A lifetest is used to determine the likely problem areas in both resonators. Recommendations are made concerning the size of rod and type of resonator configuration best able to meet the requirements of a laser suitable for airborne depth sounding.

Security classification of this page: UNCLASSIFIED

The official documents produced by the Laboratories of the Defence Research Centre Salisbury are issued in one of five categories: Reports, Technical Reports, Technical Memoranda, Manuals and Specifications. The purpose of the latter two categories is self-evident, with the other three categories being used for the following purposes:

Reports	:	documents prepared for managerial purposes.
Technical Reports	:	records of scientific and technical work of a permanent value intended for other scientists and technologists working in the field.
Technical Memoranda	:	intended primarily for disseminating information within the DSTO. They are usually tentative in nature and reflect the personal views of the author.